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Heart rate variability associated with posttraumatic stress disorder in victims' families of sewol ferry disaster

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ABSTRACT

Posttraumatic stress disorder (PTSD), which is caused by a major traumatic event, has been associated with autonomic nervous function. However, there have been few explorations of measuring biological stress in the victims' family members who have been indirectly exposed to the disaster. Therefore, this longitudinal study examined the heart rate variability (HRV) of the family members of victims of the Sewol ferry disaster. We recruited 112 family members of victims 18 months after the disaster. Sixty-seven participants were revisited at the 30 months postdisaster time point. HRV and psychiatric symptoms including PTSD, depression and anxiety were evaluated at each time point. Participants with PTSD had a higher low frequency to high frequency ratio (LF:HF ratio) than those without PTSD. Logistic regression analysis showed that the LF:HF ratio at 18 months postdisaster was associated with a PTSD diagnosis at 30 months postdisaster. These results suggest that disrupted autonomic nervous system functioning for longer than a year after trauma exposure contributes to predicting PTSD vulnerability. Our finding may contribute to understand neurophysiologic mechanisms underlying secondary traumatic stress. Future studies will be needed to clarify the interaction between autonomic regulation and trauma exposure.

1. Introduction

On April 16, 2014, the accidental sinking of the Sewol ferry occurred en route from Incheon to the island of Jeju in South Korea. There were 476 people on board, including a school party of 325 students on a field trip from a high school. In all, 246 students died and four students were missing in the disaster; only 75 of them survived. Many people criticized the action of crew members who abandoned the ship in order to be rescued earlier and the insufficient rescue response of the South Korean government. Until about two and a half years later, the Sewol ferry disaster remained a painful subject, and most of the student survivors were suffering from prolonged reexperiencing of the event. Families of the victims were still struggling for an independent investigation that would explain what had happened. However, longitudinal explorations of assessing biological stress in victims' family members of Sewol disaster are few, and neurophysiological mechanisms related to indirect exposure to trauma for a long period of time remain unclear.

Heart rate variability (HRV) is the quantitative assessment of the variation in the time interval between heartbeats, and power spectral analysis of HRV can reflect the state and integrity of the autonomic nervous system (Bilchick and Berger, 2006). Some studies have suggested that life-threatening events or trauma can be related to autonomic dysfunction (Edner et al., 2000; Lee et al., 2013). Natural disasters, such as earthquakes and hurricanes, also induce autonomic imbalance (Lin et al., 2001; Tucker et al., 2012), and bereaved individuals show a higher heart rate than depressed or control participants (O'Connor et al., 2002). In particular, the consistent findings have suggested relationship between posttraumatic stress disorder (PTSD) and reduced HRV (Dennis et al., 2014; Minassian et al., 2015; Shah et al., 2013). Because previous studies have found a significant difference in mental health problems when bereaved parents (BP) are compared to non-bereaved parents (non-BP) or bereaved offspring (Xu et al., 2013), HRV measurements can be useful to assess neurophysiological difference between BP, other bereaved relatives, and non-BP.

The unexpected death of a loved one has been found to be

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associated with a risk of PTSD (Atwoli et al., 2017; Keyes et al., 2014), and some studies have suggested that indirect exposure to trauma may be a potent factor for the development of PTSD in some individuals (Zimering et al., 2006). While approximately one half of adults recover completely from posttraumatic stress symptoms within 3 months (American Psychiatric Association, 2013), many family members of the victims of the Sewol disaster remained symptomatic after one and a half years (Huh et al., 2017). Although the association between reduced HRV and PTSD has been well documented, neurophysiological questions related to long-term symptomatic PTSD remain unanswered. Furthermore, HRV measures before and after a traumatic event have been found to be associated with a PTSD diagnosis several months after the event (Minassian et al., 2015; Shaikh al arab et al., 2012). Therefore, research that focuses on the potential of HRV as a predictor of PTSD over a long-term period is needed.

In this study, we evaluated HRV differences between BP, other bereaved relatives, and non-BP, and tested our hypothesis that student victims' family members with PTSD would have reduced HRV compared to those without PTSD. In a follow-up analysis, the family members of the student victims of the Sewol disaster were evaluated for HRV and PTSD symptoms at 18 months and 30 months after the disaster. Furthermore, we explored whether HRV frequency domain measures at 18 months after the disaster were associated with a PTSD diagnosis at 30 months after the disaster.

2. Method

2.1. Participants and procedure

The results reported here are part of a longitudinal cohort study that included physical and mental health examinations and HRV measurement at 18 (October/November 2015) and 30 months (October/November 2016) after the Sewol ferry disaster. All family members of the victims of the Sewol disaster were invited to participate in this study (in this study, "victim" refers to a person who was directly exposed to the disaster). The scheduling of the survey and distribution of the questionnaires were conducted with assistance from the Ansan Mental Health Trauma Center.

A flow diagram of the participants in this longitudinal study is presented in Fig. 1. During the first assessment at 18 months after the disaster, 112 participants who consisted of family members of the student victims of the Sewol disaster were investigated. Four participants were excluded from the data analyses due to difficult categorization. Six participants whose data were missing or who had artifacts were also excluded from the data analyses. One hundred and two participants were classified according to their relationship to the student victims of the disaster, resulting in 77 BP, 10 other bereaved relatives who had lost their siblings or grandchildren, and 15 non-BP (i.e., student survivors' parents who had been shocked by the disaster).

For the follow-up, 67 of the 112 participants (59.8%) were revisited 30 months after the disaster. Forty-five participants dropped out (44 refused to participate and one died from lung cancer). Five participants whose data were not used in the 18 months' analysis were excluded. Twelve participants were also excluded due to missing or artifact HRV. Fifty participants (36 BP, five other bereaved relatives, and nine non-BP) were used in the follow-up analysis. The study was approved by the Institutional Review Board of Seoul St Mary's Hospital, College of Medicine, The Catholic University of Korea. All participants provided written informed consent prior to participation.

2.2. Psychometric measurements

The mental health assessment included a comprehensive evaluation of the demographic data before and after the disaster, and of psychiatric symptoms using a self-report questionnaire. The PTSD symptoms were quantified using the PTSD checklist-5 (PCL-5) from the Diagnostic and Statistical Manual of Mental Disorders-5 (American Psychiatric Association, 2013), which was developed for screening PTSD symptoms based on the criteria used in the Diagnostic and Statistical Manual of Mental Disorders-5. The range of the PCL-5 is 0–80, and 38 was used as the cut-off score for the diagnosis of PTSD (Hoge et al., 2014). The Cronbach's alpha for this scale was 0.96 (Bovin et al., 2016). Considering the high prevalence rate of PTSD in this cohort, we used the PCL-5 score to categorize participants into two groups at each time point, which included participants with PTSD who scored 38 or above on the PCL-5, and participants without PTSD who scored below 38, at 18 months postdisaster (66 with PTSD vs. 36 without PTSD) and at 30 months postdisaster (37 with PTSD vs. 13 without PTSD, Table 1).

Other psychiatric symptoms associated with HRV, such as depression and anxiety disorder (Agelink et al., 2002; Chalmers et al., 2014), were also assessed. Depression was evaluated using the Patient Health Questionnaire-9 (PHQ-9), which is a multipurpose instrument for screening, diagnosing, monitoring, and measuring the severity of depression. The PHQ-9 consists of nine items, with each item rating the frequency of the symptoms according to a scoring severity index from 0 to 3. The Cronbach's alpha for this scale ranges from 0.86 to 0.89 (Kroenke et al., 2001). Anxiety was measured using the Generalized Anxiety Disorder-7 (GAD-7) scale, which is a short self-report questionnaire that was developed for the early detection of generalized anxiety disorder (Spitzer et al., 2006). It is composed of seven items and the measurement is conducted using a 4-point scale. Cronbach's alpha for this scale is 0.92.

The Life Events Checklist (LEC) was used to assess exposure to potentially traumatic events, and was strongly associated with PTSD symptoms (Gray et al., 2004). The LEC is composed of 17 items and uses five nominal levels of response: "happened to me," "witnessed it," "learned about it," "not sure," and "does not apply". This study analyzed the response as a dichotomy; that is, experience versus no experience. Answering "witnessed it" to items 14 ("witness violent death") and 15 ("sudden, unexpected death of someone close"), which specifically asked about witnessing the events, was regarded as experiencing the event (Bae et al., 2008).

2.3. Heart rate variability

The HRV measurement was performed for 5 min during the morning (9 a.m. to noon) to prevent the influence of the circadian rhythm (Rissling et al., 2016). Electrodes were attached to the participant's right and left wrists (LeBlanc et al., 2016; Sim et al., 2015) in a calm environment. The standardized short-term recording of 5 min has been widely adopted because of its cost-effectiveness and convenience (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). We used a WISE-8000 (Mooyoo Instruments, Seongnam, Korea) for the acquisition, storage, and processing of signals. After confirming that the graph was clear and had no interfering wavelengths, the electrocardiogram (ECG) recordings were collected at a sampling frequency of 500 Hz. The ECG signal was used to define the R-R intervals for the HRV calculation. The HRV analysis was completed according to the standard method described in the Task Force Guidelines (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Spectral analysis using a fast-Fourier transform algorithm was automatically performed to generate the heart period power spectrum. The power spectrum was divided into frequency domain measurements. The low frequency (LF; 0.04–0.15 Hz) and high frequency (HF; 0.15–0.40 Hz) powers (ms^2) were examined. The low frequency to high frequency ratio (LF:HF ratio), which is thought to reflect the parasympathetic and sympathetic balance, was also calculated. As the LF, HF, and LF:HF ratio were not normally distributed, natural log transformations were generated; such transformations are widely used in HRV research (Dennis et al., 2014; Minassian et al., 2015).